Jan. 13, 1953 M. P. MIDDLEMARK 2,625,655

HIGH-FREQUENCY SYSTEM EMPLOYING A REFLECTOR

Filed Aug. 26, 1952 3 Sheets-Sheet 1

Fig. 1.

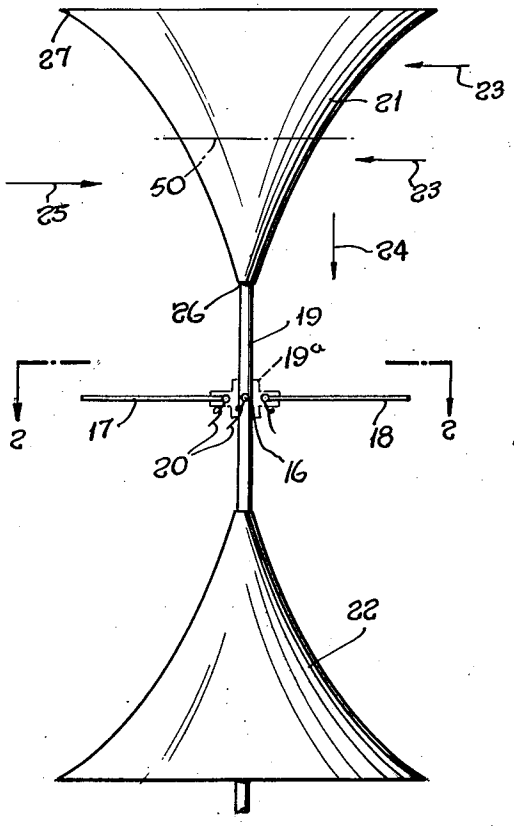
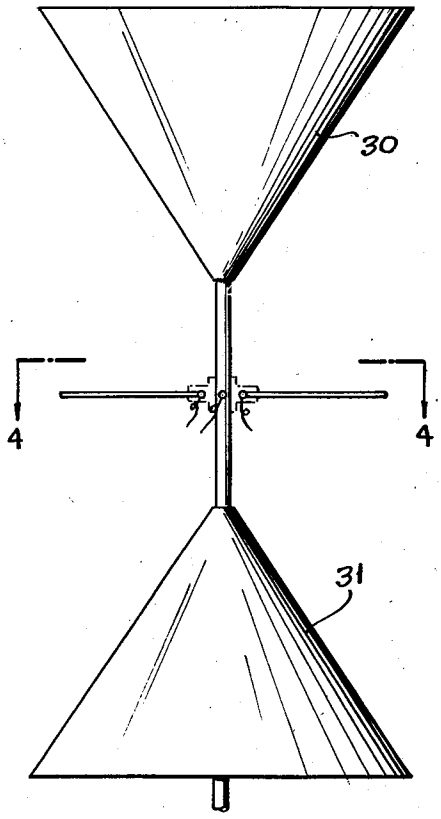


Fig. 3.



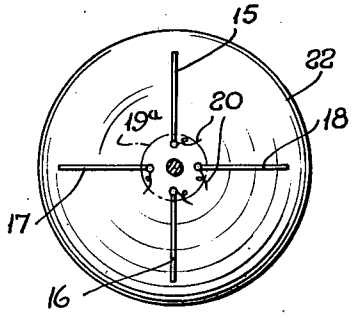
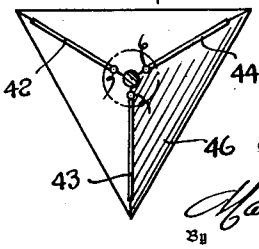


Fig. 2.

Fig. 10.



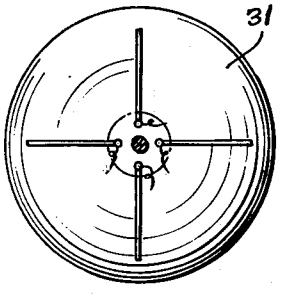


Fig. 4.

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HIGH-FREQUENCY SYSTEM EMPLOYING A REFLECTOR

Filed Aug. 26, 1952 3 Sheets-Sheet 2

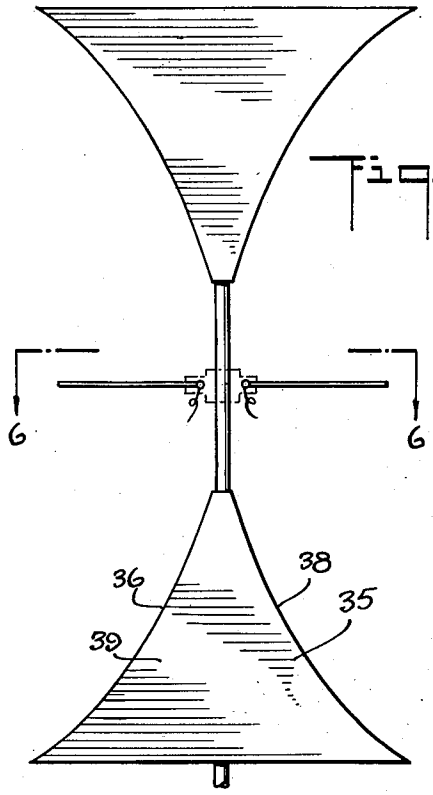

Fig. 5.

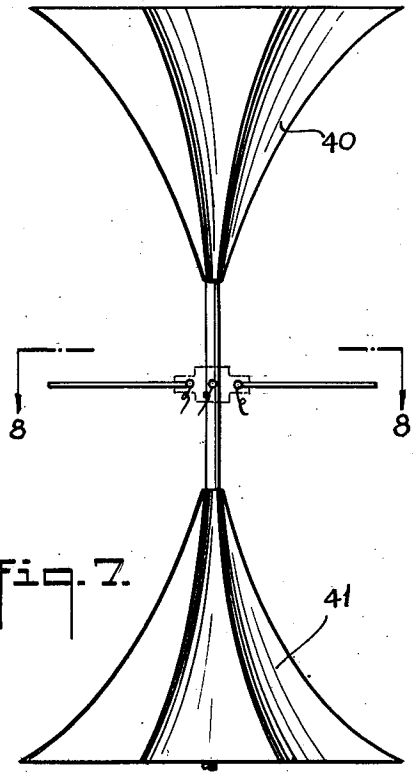

Fig. 7.

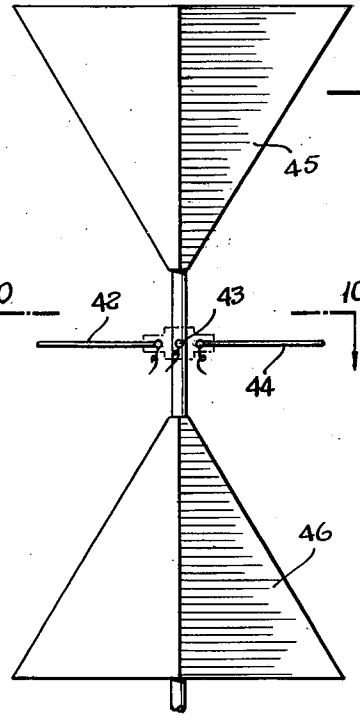

Fig. 9.

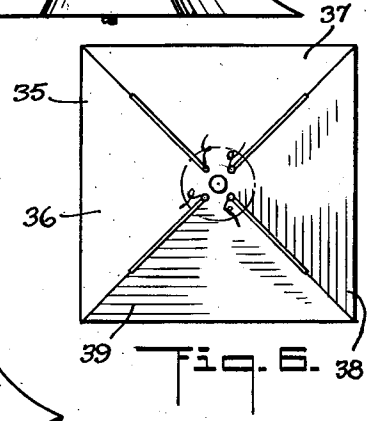

Fig. 6.

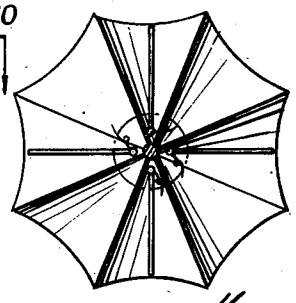

Fig. 8.

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HIGH-FREQUENCY SYSTEM EMPLOYING A REFLECTOR

Filed Aug. 26, 1952 3 Sheets-Sheet 3

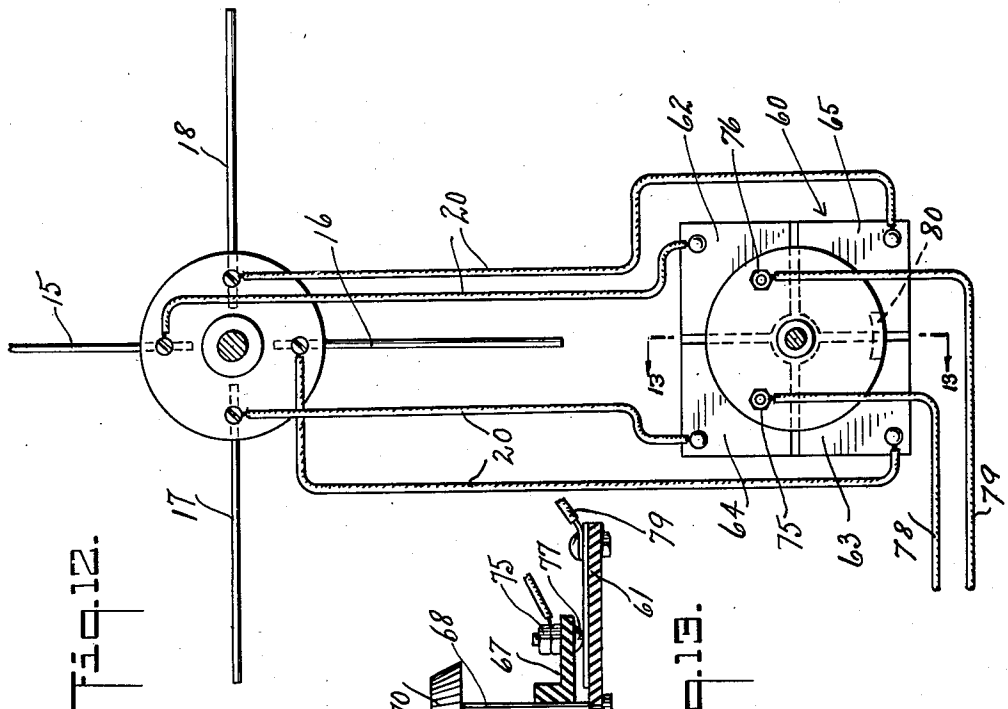

Fig. 12.

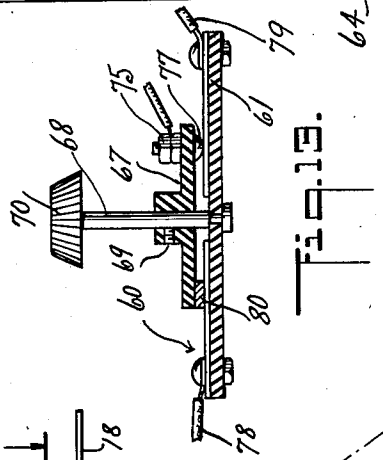

Fig. 13.

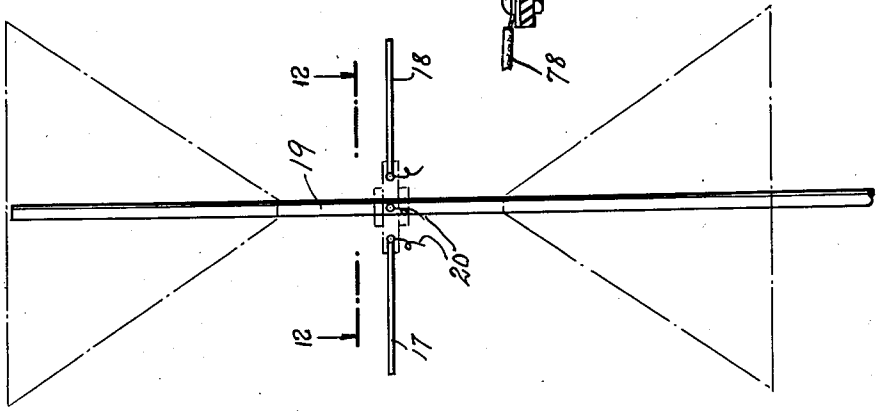

Fig. 11.

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UNITED STATES PATENT OFFICE

2,625,655

HIGH-FREQUENCY SYSTEM EMPLOYING A REFLECTOR

Marvin P. Middlemark, Woodside, N. Y.

Application August 26, 1952, Serial No. 306,460

12 Claims. (Cl. 250—33.65)

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This invention relates to high frequency antenna arrays such as may be used in television, radar and other high frequency systems.

The invention is particularly concerned with a reflector system which, as far as I am aware, occupies a novel position and functions more effectively than conventional reflectors as regards radiation which would not ordinarily be intercepted by conventional systems.

The reflector of the instant invention may further be employed in connection with an antenna which is capable of multi-directional service and without requiring rotation or any other movement thereof.

In my Patents Nos. 2,585,670 and 2,609,503, I disclosed crossed form of dipoles which, in combination with a switch, was effective in various selective directions. The broad idea of combining a switch with antenna elements for direction selection has been known but, to my knowledge, it has been difficult or impossible to devise a high gain, multi-directional reflector which adequately and automatically served any one of selected directions. I have met this problem by disposing reflector elements in substantially perpendicular or off-set relationship with the plane of the antenna as distinguished from alignment therewith as has been customary. My reflector elements may be of sheet or parabola form as will be shown hereinafter. The main principle upon which my reflector system operates is that it intercepts radiation in planes which would not be intercepted by the antenna per se and it directs the intercepted waves toward the antenna so as to increase the gain of the system, and it effects this result in all directions without requiring rotation, electrical or physical.

The invention will be further understood from the following description and drawings in which:

Figure 1 is an elevational view disclosing a preferred form of the invention;

Figure 2 is a sectional view as taken along the lines 2—2 of Figure 1;

Figure 3 is a modified form of antenna array;

Figure 4 is a sectional view as taken along the lines 4—4 of Figure 3;

Figure 5 is a second modified embodiment;

Figure 6 is a sectional view as taken along the lines 6—6 of Figure 5;

Figure 7 is a third modified embodiment;

Figure 8 is a sectional view as taken along the lines 8—8 of Figure 7;

Figure 9 is a fourth modified embodiment;

Figure 10 is a sectional view as taken along the lines 10—10 of Figure 9;

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Figure 11 is an elevational view similar to Figure 1 and wherein the reflectors are in broken lines to represent any of the horn-shaped reflectors as set forth in this application;

Figure 12 is a view taken along the lines 12—12 of Figure 11 with a selector switch connected to the antenna leads; and

Figure 13 is a cross-sectional view of the selector switch as taken along the lines 13—13 of Figure 12 with a knob added thereto.

Referring now to Figures 1 and 2, the fed or primary elements of the antenna array comprise the dipole rods 15 and 16 forming one dipole and the rods 17 and 18 forming another dipole which is crossed relative to the first dipole. All the dipole rods 15 to 18 are therefore arranged in stellate form since they radiate outwardly from a common center, said center, in the form shown, being the mast 19. The rods are connected to a conventional form of insulating bracket 19a which is itself mounted on the mast. Such an antenna, comprising two crossed dipoles, is often referred to as a turnstile antenna. A more complete description thereof including the function of the wires 20 which are connected to the four inner terminal ends of the dipole rods, is described in my above mentioned patents. Briefly, each of the wires 20 may be connected to a switch which serves to select proper combinations of the dipole rods depending upon the directivity desired.

Connected to the mast 19 are a pair of reflector elements 21 and 22. In the first embodiment illustrated, these reflector elements take the form of exponential horns. The function of the reflectors 21 and 22 is to intercept waves such as those which travel in the direction of the arrows 23, and reflect and focus them downwardly in the direction of the arrow 24 where they are intercepted by the antenna dipole rods so as to induce a voltage therein according to well known principles of antenna reception. Thus, the horns function as does a parabola in respect to primary radiation collected by the parabola save that the horns are spaced vertically above and below the antenna dipole rods rather than behind them.

Inasmuch as each horn is radially uniform, it can serve as a reflector for waves arriving from any direction. For example, if we have selected such dipole elements as would receive waves arriving from the direction indicated by the arrow 25, the reflector 21 will intercept such waves from its left-hand surface as viewed in Figure 1 and will direct them downwardly as above described. Of course, the antenna will serve its conventional

function of directly intercepting waves in addition to those received from the reflector. The reflector 22 will function identically as reflector 21 for waves intercepted below the dipole elements.

Insofar as the waves indicated by arrow 25 are concerned, the surface of the reflector 21 which serves said wave is a concave section which is tilted diagonally in a vertical plane so that its lower end or apex 26 is closer to the antenna elements than is its upper end or mouth 27. Every wave which arrives from a different direction will be accommodated by a like area around the periphery of reflector 21. Thus, irrespective of which combination of antenna elements are chosen to select a different direction, the reflectors will direct the proper waves thereto so as to greatly increase the sensitivity and gain of the system, this being accomplished without requiring any movement of the reflectors. It will be observed that regardless of where a wave may strike along the length of the horn, it will arrive, by reflection, at the antenna in the same phase. The particular operation of the reflectors illustrated, follows known principles of reflecting surfaces in antenna radiation including the modified impedance characteristics of the primary antennas with different forms of reflectors.

In Figure 3 is illustrated a modification where the reflectors 30 and 31 are conical rather than exponential. The function of the reflectors is the same as in the first embodiment save that the exponential reflector may be considered a more positive means of focusing radiation in the manner of a parabola particularly for the higher frequencies.

In Figure 5 is illustrated an antenna reflector of the foregoing types which is not only exponential but of pyramid form. Thus, the reflector 35 is formed with four sides, 36, 37, 38 and 39. An arrangement of this type is considered to be of some advantage in that it provides a larger surface for intercepting radiation and directing such radiation downwardly in any one direction. Each side may be considered to be of triangular shape and having a top horizontally disposed side and an apex at the lowermost point. The bisector of the lowermost apex angle is the same vertical plane as the bisector of the angle formed by the two adjacent dipole rods which it serves.

In Figure 7 is disclosed an antenna which combines the advantages of Figure 5 with a paraboloid surface in that reflector horns 40 and 41 comprise a series of fluted, exponentially curved or substantially ellipsoidal segments. In the form shown, eight such fluted sections are provided as shown in Figure 8. A wave coming from any direction will meet one of the fluted sections and will be intercepted and directed downwardly as above described. Such a surface is of particular value since there exists greater probability of supporting equal angle of incidence and reflection.

In Figures 9 and 10 are illustrated yet another form wherein the antenna per se, comprises only three elements 42, 43 and 44, spaced 120° apart. In this case, by way of illustration, the reflectors 45 and 46 may take the form of triangular pyramids each comprising three plane surfaces, each serving any two adjacent pair of dipole rods. It will be understood that the reflectors 45 and 46 may assume the various forms above described.

In regard to the vertical spacing of the reflectors above and below the antennas per se, it is believed that the center of the reflector as indicated by the line 50 in Figure 1, should be arranged at the conventional distance employed in reflectors depending upon the frequencies involved and other requirements which are well understood. As will be recognized, the band width is narrow for small spacings whereas with wide spacings the gain is less but the band width is larger. The spacing may be anywhere from 0.1 to 1.0 wave length, these figures being merely representative. Inasmuch as the antenna serves a wide band, an intermediate or favored frequency may be chosen to determine the spacing in terms of wave length. Furthermore, a tuning circuit may be connected between the reflectors and ground so as to vary the phase of the reflected energy as will be well understood.

The length of the reflectors will largely be determined by the length of the dipole rods since the use of considerably overlapping reflectors is not of particular advantage. As an example, if each dipole rod is 25", the height of each horn from the apex to the center of the mouth thereof, may be approximately 40".

In all of the above embodiments, the gain of the antenna will be amplified regardless of the direction of arrival of the waves. When particular combinations of dipoles are selected to achieve directivity in desired directions, as set forth in my above mentioned patents, the reflectors will automatically and inherently direct the appropriate waves toward the antenna so as to substantially increase the gain of the system.

As described in my above mentioned patents, and in application Serial No. 241,959, filed August 15, 1951, of which said patents are continuations as set forth therein, the direction selection may be accomplished by a selector switch having means to select various pairs of the various antenna dipole rods for connection to the input terminals of a television receiver. Such a switch is shown in Figures 12 and 13, being a duplicate of that disclosed in application Serial No. 241,959.

The four wires 20 are connected to the respective inner terminal ends of dipole rods 15 to 18. These wires, which may be of the transmission line type, are connected at their other ends to sections of the switch 60, the switch being thereafter manually operated by the user of the television receiver in order to select the proper effective direction and thus secure the best reception. Switch 60 includes a plate 61 having four angularly arranged conducting sections 62, 63, 64 and 65. Plate 61 is itself of insulating material while the sections 62 to 65 may comprise metallic inserts secured or coated thereon. Switch sections 62 to 65 are insulated from each other by the perpendicularly related lines of spacing between them as illustrated in Figure 12.

Switch plate 61 is a stationary member of switch 60 and a rotatable selector dial member 67 is provided. Dial 67 is secured to shaft 68 as by a set screw 69. An operating knob 70 is secured to shaft 68. Loosely mounted on a reduced portion of shaft 68 is the plate 31 which will further be restrained against any rotation as by connection thereof to a frame or body or the like. Accordingly, manual rotation of knob 70 rotates dial 67 relative to plate 61 over which it is superimposed.

Selector dial 67 includes a pair of output terminal members 75 and 76 which are offset from the center of the dial as represented by the shaft 68. Terminals 75 and 76 may take the form of metallic bolts 77, the dial 67 being itself of insulating material. Wires 78 and 79 are connected

to the input of the television receiver so as to feed the antenna signal thereto.

The construction of switch 60 is such as to effectively select any two of the four quadrant switch sections 62 to 65 for application to the input of the television receiver. Thus, if the dial 67 is turned in the position illustrated in Figure 12, the switch terminals 75 and 76, by virtue of their offset and angular disposition, reach past the lines of insulation and effect electrical contact by wiping action over switch sections 62 and 64 so as to feed the energy collected by dipole rods 15 and 17 to the television receiver. It will be evident that turning of the selector knob to rotate the switch terminals 75 and 76 will effectively select various combinations of dipole rods and will select corresponding directions. The switch 60 also includes means for shorting or bridging certain non-selected dipole rods so that they may serve as a reflector. To this end, a conducting or shorting member 80, is formed on the underside of dial 67. It will be observed in Figure 12 that switch sections 63 and 65 are effectively shorted while sections 62 and 64 are selected for directivity. This means that dipole rods 16 and 18 are connected so as to serve as a reflector for rods 15 and 17.

It will be understood that the construction of the switch 60 follows exactly the switch construction described in my above mentioned application Serial No. 241,959, has been described for explanatory purposes and is not claimed in this particular application. Other selector switches such as set forth in my above mentioned patents, may be employed for the same purpose.

The reflectors have been illustrated as being plane or curved sheets or the like but it will be evident that conventional substitutes therefor such as wire netting or spines may be employed.

I have described my invention as operating on the principle of reflecting radiation downwardly to the antenna but this is not intended to exclude the idea that conventional inter-action or re-radiation between the antenna dipoles and the reflectors may occur. With respect to radar or similar applications, it will be evident that the instant invention makes possible the physical or electrical rotation of the primary antenna elements without a corresponding rotation of a parabola or other reflector element. Such rotation may be accomplished by a manually or motor operated switch and all direction antenna combination such as of the type described in my above mentioned patents. For example, by operating the shaft of the switch illustrated in my Patent No. 2,585,670 by a motor which rotates it over sixteen revolutions per second or at any speed necessary to maintain persistence of vision on a cathode ray tube, in conjunction with an omni-directional antenna as disclosed therein, and employing a reflector system as herein illustrated, I am enabled to secure effective rotation of the entire system while the reflectors remain stationary whether or not the antennas rotate. This will simplify the construction and operation problems of large arrays to a considerable extent. It will be further understood that the invention may be employed in either receiving or transmitting systems and, with proper re-orientation of the elements to serve vertically polarized waves, will be applicable to vertically polarized systems.

What is claimed is:

1. An antenna system comprising a plurality of substantially horizontal antenna elements diverging from a common center, means to select different combinations of said antenna elements for connection to the input terminals of a television receiver so as to vary the directivity of reception, and a reflector therefor, said reflector comprising a horn-shaped member having its axis vertical and in coincidence with said center of said horizontal antenna elements, said horn-shaped reflector being vertically spaced from said antenna elements.

2. An antenna system comprising a plurality of substantially horizontal antenna elements diverging from a common center, a selector switch having a pair of output terminals, means to selectively, electrically connect said output terminals to any pair of said antenna elements so as to vary the directivity of reception, and a reflector therefor, said reflector comprising a horn-shaped member having its axis vertical and in coincidence with said center of said horizontal antenna elements, said horn-shaped reflector being vertically spaced from said antenna elements.

3. An antenna system comprising a plurality of substantially horizontal antenna elements diverging from a common center, a selector switch for selecting different combinations of said antenna elements for connection to the input terminals of a television receiver so as to vary the directivity of reception, and a pair of horn-shaped reflectors respectively disposed above and below said antenna elements, each reflector having its axis vertically disposed in alignment with each other and with the center of said horizontal antenna elements, the apices of the horns facing each other and the mouths of the horns being outwardly directed.

4. A system according to claim 3 and wherein the outer surface of each horn reflector is of exponential form.

5. A system according to claim 3 and wherein each of said reflectors are conical with the apices of each cone facing each other and the mouths of the cones being oppositely directed.

6. A system according to claim 3 and wherein said antenna elements comprise a pair of dipoles crossed perpendicularly so as to form a cross.

7. A system according to claim 3 and wherein said antenna elements comprise a pair of dipoles crossed perpendicularly so as to form a cross, each of said reflectors comprising a four-sided pyramid, each side being of substantially triangular shape with the apex angle thereof facing the antenna elements, and the bisector of each apex angle being in the same vertical plane as the bisector of two adjacent horizontal antenna elements.

8. An antenna system comprising three substantially horizontal antenna elements diverging from a common center and all normally insulated from each other, a selector switch for selecting different pairs of said antenna elements for respective connection to the input terminals of a television receiver so as to selectively vary the effective directivity of the system, and a reflector for said antenna elements, said reflector comprising a three-sided pyramid-shaped member having its longitudinal axis vertical and in coincidence with the center of said horizontal antenna elements, said reflector being vertically spaced from said horizontal antenna elements with its apex facing in the direction of said horizontal antenna elements.

9. An antenna system comprising a plurality of substantially horizontal antenna elements diverging from a common center, a selector switch for selecting different pairs of said antenna elements

for respective connection to the input terminals of a television receiver so as to selectively vary the effective directivity of the system, and a reflector, said reflector comprising a horn-haped, elongated member having its longitudinal axis vertical and in alignment with the center of said horizontal antenna elements, said horn-shaped reflector being vertically spaced from said horizontal antenna elements and comprising a plurality of fluted segments from the top to the bottom thereof.

10. An antenna system according to claim 9 and including a second reflector having the same shape as said first-named reflector and being vertically spaced below said horizontal antenna elements with the base or apex of the horn-shaped reflector closer to said antenna elements than the mouth thereof, said first-named reflector being vertically spaced above said horizontal antenna elements.

11. An antenna system comprising a plurality of substantially horizontal antenna elements, all being normally insulated from each other and diverging from a common center and equally spaced around 360° of a circle, a selector switch for selecting different pairs of said antenna elements for respective connection to the input terminals of a television receiver so as to selectively vary the effective directivity of the system, and a reflector for said antenna elements, said reflector comprising an elongated horn-shaped member having its longitudinal axis vertical and in coincidence with the center of said horizontal antenna elements, said horn-shaped reflector being vertically spaced from said horizontal antenna elements with the apex of the horn closer to said horizontal antenna elements than the mouth thereof.

12. An antenna system comprising a pair of crossed dipoles adapted to selectively intercept radiation from substantially every horizontal direction around 360° of a circle, each of said dipoles comprising two dipole rods so that said pair of crossed dipoles comprise four dipole rods, means to select any two of said dipole rods for connection to the input terminal of a television receiver so as to selectively vary the direction of reception, and a pair of stationary, horn-shaped reflector members mounted on said mast and each being respectively spaced from said pair of crossed dipoles on both sides thereof, each of said reflector members being adapted to intercept radiation from every horizontal direction around 360° of a circle and reflect it toward the pair of crossed dipoles.

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